TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 681

A GENERAL TANK TEST OF A MODEL OF THE HULL OF THE P3M-1 FLYING BOAT INCLUDING A SPECIAL WORKING CHART FOR THE DETERMINATION OF HULL PERFORMANCE

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SUMMARY

The results of a general tank test of a 1/6-full-size model of the hull of the P3M-1 flying boat (N.A.C.A. model 18) are given in nondimensional form. In addition to the usual curves, the results are presented in a new form that makes it possible to apply them more conveniently than in the forms previously used.

The resistance was compared with that of N.A.C.A. models 11-C and 26 (Sikorsky S-40) and was found to be generally less than the resistance of either.

INTRODUCTION

The research program for the N.A.C.A. tank includes the testing of models of hulls that have been successfully used in actual flying boats. The data accumulated from such a series of tests should indicate the relative merits of the various types of hull that have been developed. Previous tests have included models of a number of hulls of foreign design as well as some of those developed in this country.

Because some difficulty had been experienced with the spray from the hull of the Navy P3M-1 flying boat, a 1/6 full-size model of this hull was tested with several forms of spray strips; the results of the tests, which were made for only one load and get-away speed, are reported in reference 1. In these first tests, the spray thrown by the model did not appear to be excessive and the water resistance compared favorably with the resistance of other models. On account of the satisfactory results obtained in the tests with one load, a general tank test has been made with this model to obtain more complete data regarding its performance.

The manner in which the results of general tank tests have usually been presented has a number of disadvantages. These disadvantages can be overcome to some extent by plotting the data with a different arrangement of the variables. In order to demonstrate the advisability of presenting the data in this new manner, the data from the present tests will be presented in both the old and the new forms.

THE MODEL

The model as tested consisted of the same wooden model of the main hull that was used in the tests reported in reference 1. The lines of the model are shown in figure 1 and the offsets are given in table I. The position of the center of moments shown in figure 1 was used in the present tests.

The particulars of the model and of the full-size flying boat are as follows:

	Model	Full-size
Length:		
Over-all	117.50 in.	58 ft. 9 in.
Of forebody to main step. .	50.83 in.	25 ft. 5 in.
Maximum beam	16.84 in.	8 ft. 5 in.
Center of moments forward of step	8.33 in.	4 ft. 2 in.
Center of moments above keel	13.18 in.	6 ft. 7 in.
Depth of step	0.64 in.	3-7/8 in.
Angle of keel aft of step to base line	6° 15'	
Linear ratio of model to full size		1/6

Beam:

Percentage of over-all length	14.33
Percentage of forebody length	33.13

Forebody:

Percentage of over-all length	43.26

Center of moments, distance forward of the step:

Percentage of over-all length	7.09
Percentage of forebody length	16.39

Center of moments, distance above the keel:

Percentage of over-all length	11.22
Percentage of forebody length	25.95

APPARATUS AND PROCEDURE

The apparatus and procedure for the general tank test are described in reference 2. A general free-to-trim test was made and the results were published in reference 3. In a general test, the water resistance of a model for a number of constant loads is obtained throughout the speed range considered practicable. In the general fixed-trim test, the trim is fixed and trimming moments are measured, tests being made at a sufficient number of trims to determine the trim for minimum resistance, i.e., best trim. In the general free-to-trim test the model is balanced to bring the center of gravity to the desired position and allowed to pivot freely about a transverse axis through the center of gravity; trim is measured for each load and speed tested.

Most of the present tests were made in the fall of 1936. Analysis of the data having indicated that additional data would be desirable, further tests were made in the fall of 1937. Some differences were obtained at speed coefficients greater than 7.0, and, since it was believed that the tares (which increase with speed coefficient) were obtained more accurately in the later tests, all test points obtained in the 1936 tests at speed coefficients greater than 7.0 were repeated in 1937; the 1936 data in this region are omitted from the present report. The differences obtained in the two tests in this high-speed region would not, in general, greatly affect performance calculations.

RESULTS

The nondimensional coefficients commonly in use at the N.A.C.A. tank are defined as

Load coefficient, $C_\Delta = \dfrac{\Delta}{wb^3}$

Resistance coefficient, $C_R = \dfrac{R}{wb^3}$

Speed coefficient, $C_V = \dfrac{V}{\sqrt{gb}}$

Trimming-moment coefficient, $C_M = \dfrac{M}{wb^4}$

Draft coefficient, $C_d = \dfrac{d}{b}$

where Δ is load on water, lb.

w, specific weight of water, lb./cu. ft. (w = 63.3 lb./cu. ft. in these tests).

b, beam of hull, ft.

V, speed, f.p.s.

M, trimming moment, lb.-ft.

g, acceleration of gravity, ft./sec.^{2}

d, draft at step, ft.

Any consistent system of units may be employed.

The air drag of the model is included in the water resistance. Moments tending to raise the bow are considered positive.

The fixed-trim data are presented in figures 2 to 7, in which resistance coefficient and trimming-moment coefficient are plotted against speed coefficient with load coefficient as parameter, each figure being for one trim τ. Trim is the angle between the horizontal and the base line (fig. 1).

The original free-to-trim data are shown in figure 8 in which resistance coefficient and trim are plotted against speed coefficient with load coefficient as parameter. This figure is from figure 5 of reference 3.

The static data are presented in figure 9 in which trimming-moment coefficient and draft coefficient are plotted against load coefficient with trim as parameter.

Owing to the number of independent variables in a general tank test, it is customary to eliminate the variable, trim, by finding the trim that gives minimum resistance for each speed and load tested. This best trim has been found in the usual manner (see reference 4) for the present data and the usual curves obtained are shown in figures 10 to 13. Figure 10 shows the resistance coefficient at best trim plotted against speed coefficient with load coefficient as parameter. Figure 11 shows the same data plotted against load coefficient with speed coefficient as parameter. In figure 12, best trim τ_o is plotted against speed coefficient and, in figure 13, the trimming-moment coefficient obtained at best trim is plotted against speed coefficient, load coefficient being the parameter in both cases.

Plotting the best-trim data in this manner allows the ready finding of the least resistance that would be obtained from the hull under any condition within the range of the test. It also permits the trims required to give the least resistance and the trimming moments necessary to hold those trims to be obtained. If, however, conditions prevent the obtaining of the best trim or circumstances are such that the trim for minimum water resistance will not give a minimum of the sum of the water resistance and the air drag, then the best-trim curves are inadequate. When, because of lack of control, best trim cannot be obtained, an approximation to the condition can sometimes be made by using free-to-trim data. In general, however, when the best-trim data were inadequate, it has been desirable to compute from the curves of original test data the resistance resulting from the conditions assumed. The curves of original data are not very convenient for interpolating for a number of reasons, an important one being that it frequently is necessary to interpolate for trim from sheet to sheet. This difficulty in interpolation can be overcome by referring directly to the group of cross plots used in obtaining the best trim curves. These plots have previously been omitted from N.A.C.A. publications because they seemed to add unnecessarily to the already bulky sets of data. A method of presenting the data that increases the convenience of use without increasing the bulk of the curves is to omit both the curves of original test data and the curves of best-trim data and to substitute for them the cross plots. All the data found in either of the curves that have been omitted can be included in the cross plots. Apparently the only sacrifice made by presenting the data in this manner is the loss of a view of the variation of the dependent variables with speed, although this view can be obtained by close examination of the cross plots.

The usual cross plots of resistance coefficient are shown in figure 14. Resistance coefficient is plotted against trim with load coefficient as parameter, a set of curves being made for each of a number of speed coefficients. Similar plots were made for the trimming-moment coefficients but the data from those cross plots are shown in figure 14 in the form of curves of constant trimming-moment coefficient superposed on the resistance curves. The speed coefficients used are selected to cover the range of the tests in such a manner that interpolation for other speed coefficients may be made without sensible loss of accuracy. The symbols shown in figure 14 do not indicate test points but denote points taken from the faired curves of the original test data (figs. 2 to 8).

It should be noted that the data from the general free-to-trim tests are included in these cross plots because these data represent the conditions of zero moment. The line of best trim is shown on the curves of resistance coefficient. This line aids in the determination of the best-trim data given in figures 10 to 13. The resistance coefficient for load coefficients other than those actually tested has been indicated in figure 14 by broken lines obtained by cross-plotting resistance coefficient against load coefficient for each trim. These lines are added to aid in interpolating for load coefficient and do not differ sensibly from curves that would have been obtained had the variation of resistance coefficient with load coefficient been assumed to be linear between any two successive load coefficients tested.

It is proposed that, except in special cases, curves similar to those of figure 14 shall in future papers be presented to show the results from general tank tests, without the additional plots of figures 2 to 8 and 10 to 13. These curves are, in general, quite adequate for any problem that can be solved with data from a general tank test and, in a great many cases, they give the required answer with the least labor. The resistance corresponding to zero trimming-moment coefficient (free-to-trim) or any other assumed trimming-moment coefficient may be obtained with equal facility. If data are wanted for any center of gravity other than the one corresponding to the center of moments used in the general tests, the trimming-moment coefficient may be corrected for the differences between the two positions by calculation; these curves may then be used to show the results of such changes. The effect of inadequate controlling moment on resistance is probably more readily shown on this type of plot than on any other.

COMPARISONS

The resistance coefficients of N.A.C.A. models 18, 26, and 11-C are compared in figure 15. In this figure, the resistance coefficients at best trim are plotted against speed coefficient for selected load coefficients. The data for models 26 and 11-C are from references 5 and 6. A direct comparison of the curves of figure 15 assumes that, for a given load, the hulls of each of the three models under consideration will have the same beam. If the tail extension, which is used primarily for carrying control surfaces, is neglected, the three models, 18, 11-C, and 26, are of about the same proportions so that comparisons based on equal beams assume that the hulls will be about the same size.

The curves of figure 15 indicate that, under practically all the conditions shown, the resistance of model 18 is less than that of either model 26 or model 11-C. Model 18 appears to have very good resistance characteristics for a hull of its type and proportions.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 5, 1938.

REFERENCES

1. Dawson, John R.: The Effect of Spray Strips on a Model of the P3M-1 Flying-Boat Hull. T.N. No. 482, N.A.C.A., 1933.

2. Allison, John M.: Tank Tests of a Model of the Hull of the Navy PB-1 Flying Boat - N.A.C.A. Model 52. T.N. No. 576, N.A.C.A., 1936.

3. Dawson, John R.: Tank Tests of Two Models of Flying-Boat Hulls to Determine the Effect of Ventilating the Step. T.N. No. 594, N.A.C.A., 1937.

4. Shoemaker, James M., and Parkinson, John B.: A Complete Tank Test of a Model of a Flying-Boat Hull - N.A.C.A. Model No. 11. T.N. No. 464, N.A.C.A., 1933.

5. Dawson, John R.: A Complete Tank Test of the Hull of the Sikorsky S-40 Flying Boat - American Clipper Class. T.N. No. 512, N.A.C.A., 1934.

6. Dawson, John R.: A General Tank Test of N.A.C.A. Model 11-C Flying-Boat Hull, Including the Effect of Changing the Plan Form of the Step. T.N. No. 538, N.A.C.A., 1935.

TABLE I. Offsets for N.A.C.A. Model 18 (P3M-1) Flying-Boat Hull (Inches).

Station	Distance from F.P.	Distance from base line								Half-breadths							Crown radius
		Keel [1]A	B1 [2]1.83	B2 3.67	B3 5.50	Main chine [1]B	Upper chine [1]C	Straight bottom chine [1]E	Cove [1]F	Chine [1]G	Cove [1]H	Bottom tangency [1]J	Deck	WL3 [3]7.86	WL4 5.89	WL5 3.93	[1]K
F.P.	0.00																
1/4	.92	4.18	4.18										3.12			3.09	
1/2	1.83	5.36	5.36										3.46			3.60	
3/4	2.75	6.53	6.53	5.40									3.77		3.43	3.98	
1	3.66	7.40	7.04	6.75		6.75				3.69			4.03		4.03	4.36	
2	7.33	9.78	8.67	7.55	4.33 6.96	6.94				5.54			4.87	3.15	5.57	5.42	
4	14.67	11.74				8.32		7.84		7.33		5.07					7.33
6	22.00	12.78				9.80		9.18		8.17		5.53					8.17
8	29.33	13.33				10.52		9.87		8.42		5.67					8.42
10	36.67	13.59				10.81		10.17		8.42		5.67					8.42
12	44.00	13.68				10.94		10.27		8.42		5.67					8.42
14	50.83	13.83 13.19				11.08 10.42	9.72	10.42 9.78	9.72	8.42	8.42	5.67					8.42
16	58.56	↑				9.67	8.53	9.05	8.62	8.32	8.08	5.43					8.32
18	66.29					9.15	7.44	8.72	7.92	8.02	6.70	4.65					8.03
20	74.02	↓				9.10	6.44	8.96	7.77	7.44	4.25	2.97					7.51
22	81.75	9.80 8.24				9.80	5.56	9.80	8.24	6.64	.17	.17					6.74
24	89.50	↑					4.77			5.63							5.70
26	97.25						4.03			4.41							4.43
28	105.00						3.43			2.92							2.92
30	112.75	↓					2.90			1.24							1.24
A.P.	117.50	2.57					2.57			.21							.21

[1]Letters refer to dimensions on figure 1.

[2]Distance from center line (plane of symmetry) to buttock (section of hull surface made by a vertical plane parallel to plane of symmetry).

[3]Distance from base line to water line (section of hull surface made by a horizontal plane parallel to base line).

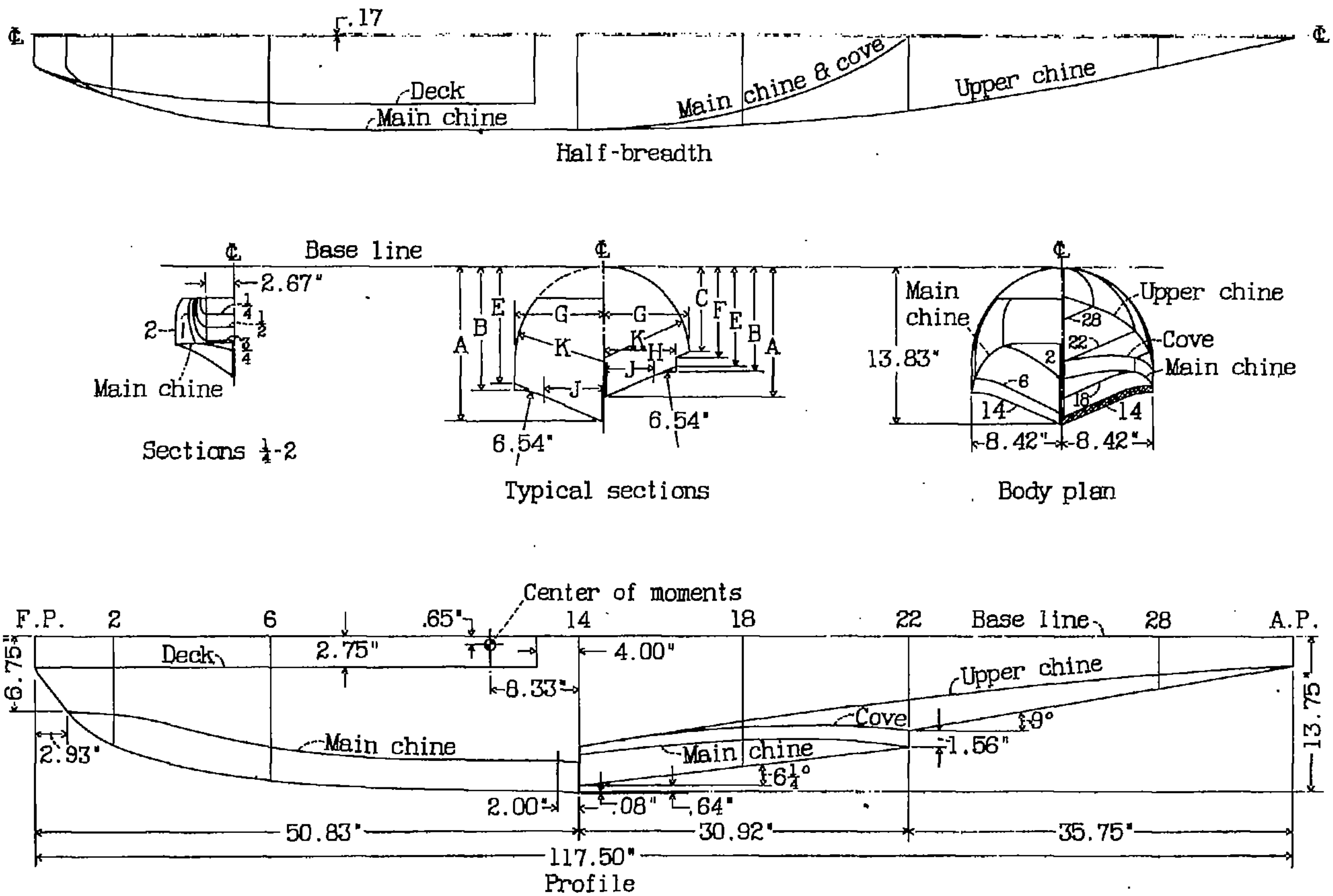


Figure 1.- Lines of N.A.C.A. model 18 (P3M-1).

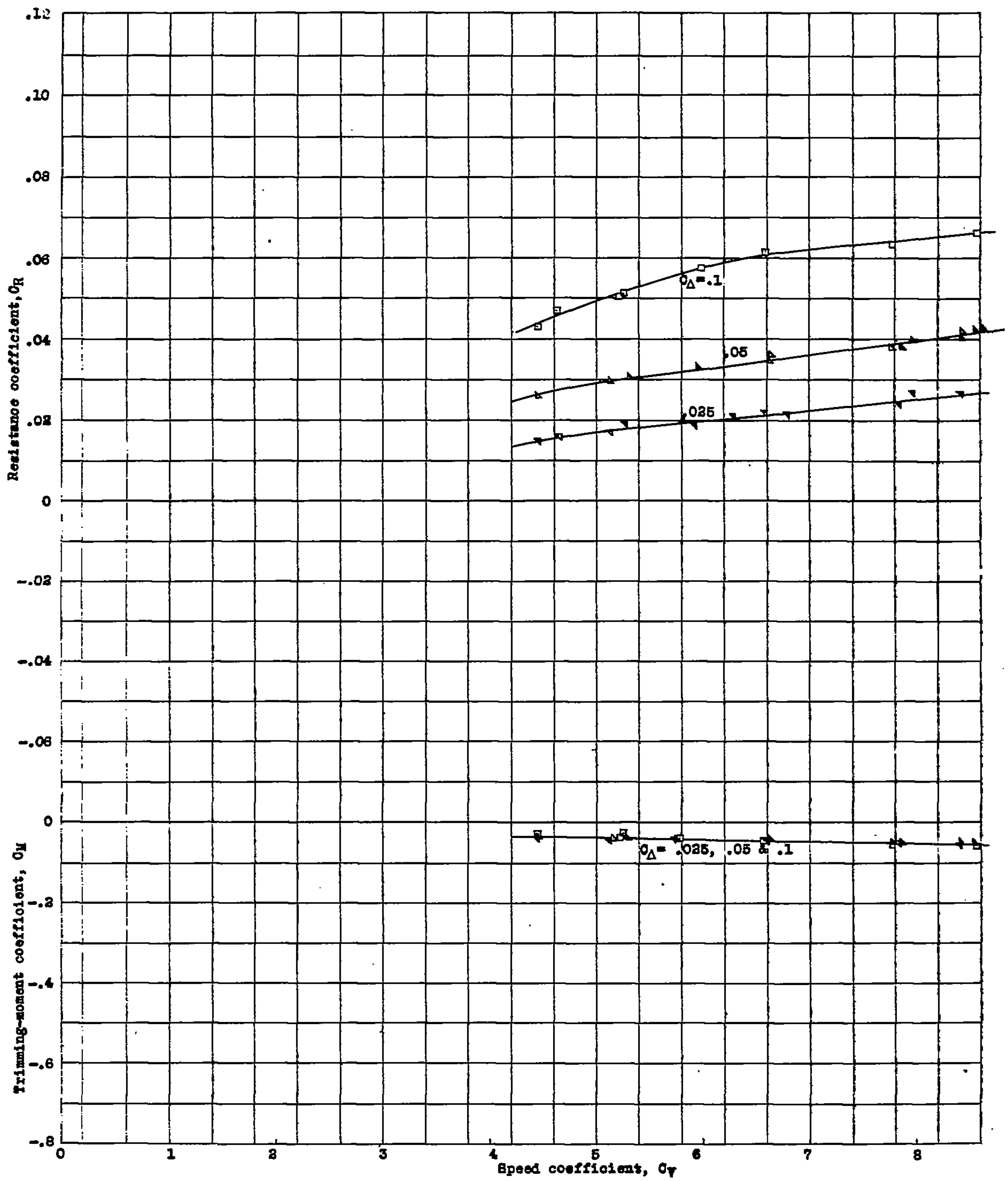


Figure 2.- Model 18. Variation of resistance coefficient and trimming moment coefficient with speed coefficient. $\tau = 1^\circ$.

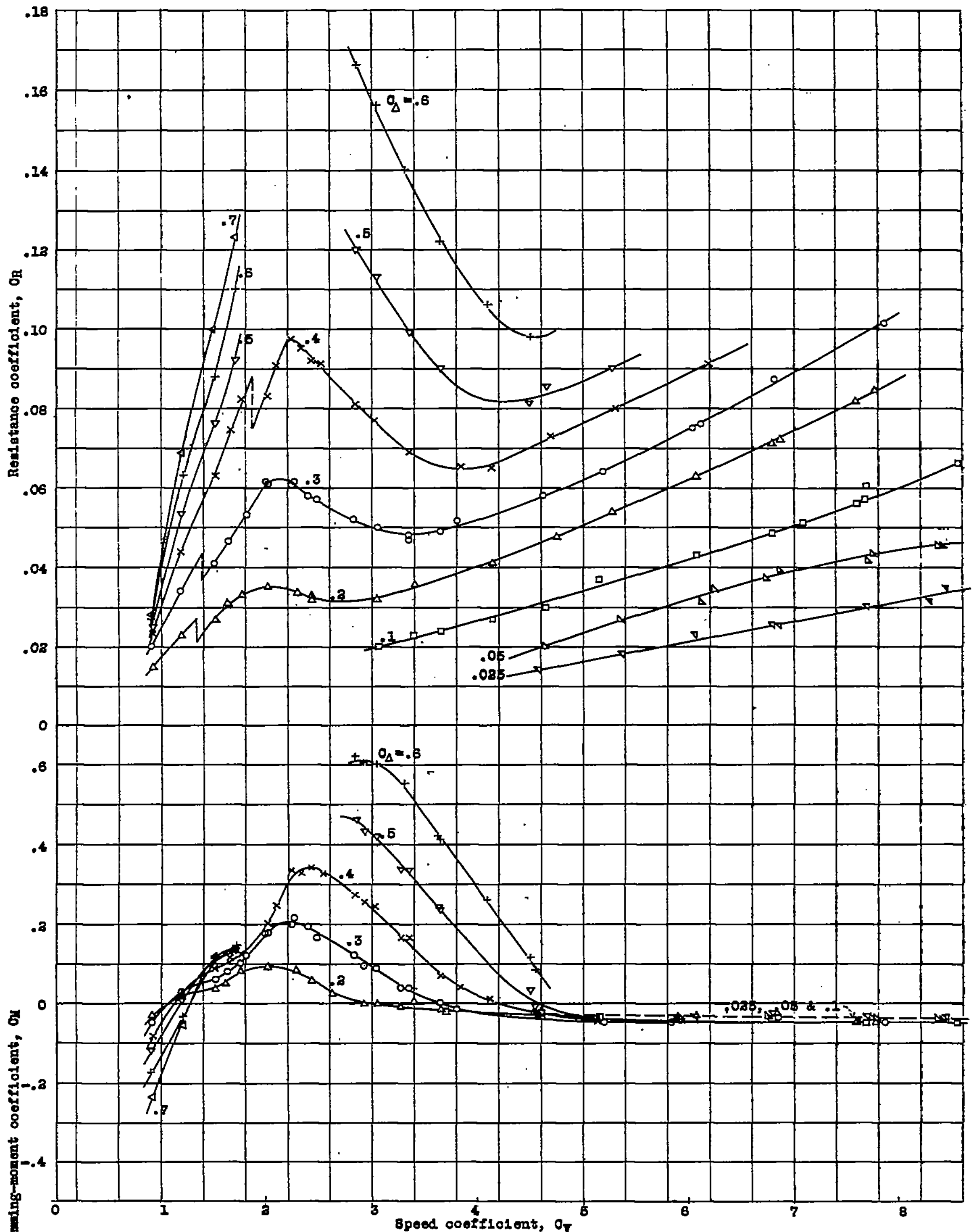


Figure 3.- Model 18. Variation of resistance coefficient and trimming-moment coefficient with speed coefficient. $\tau = 3°$.

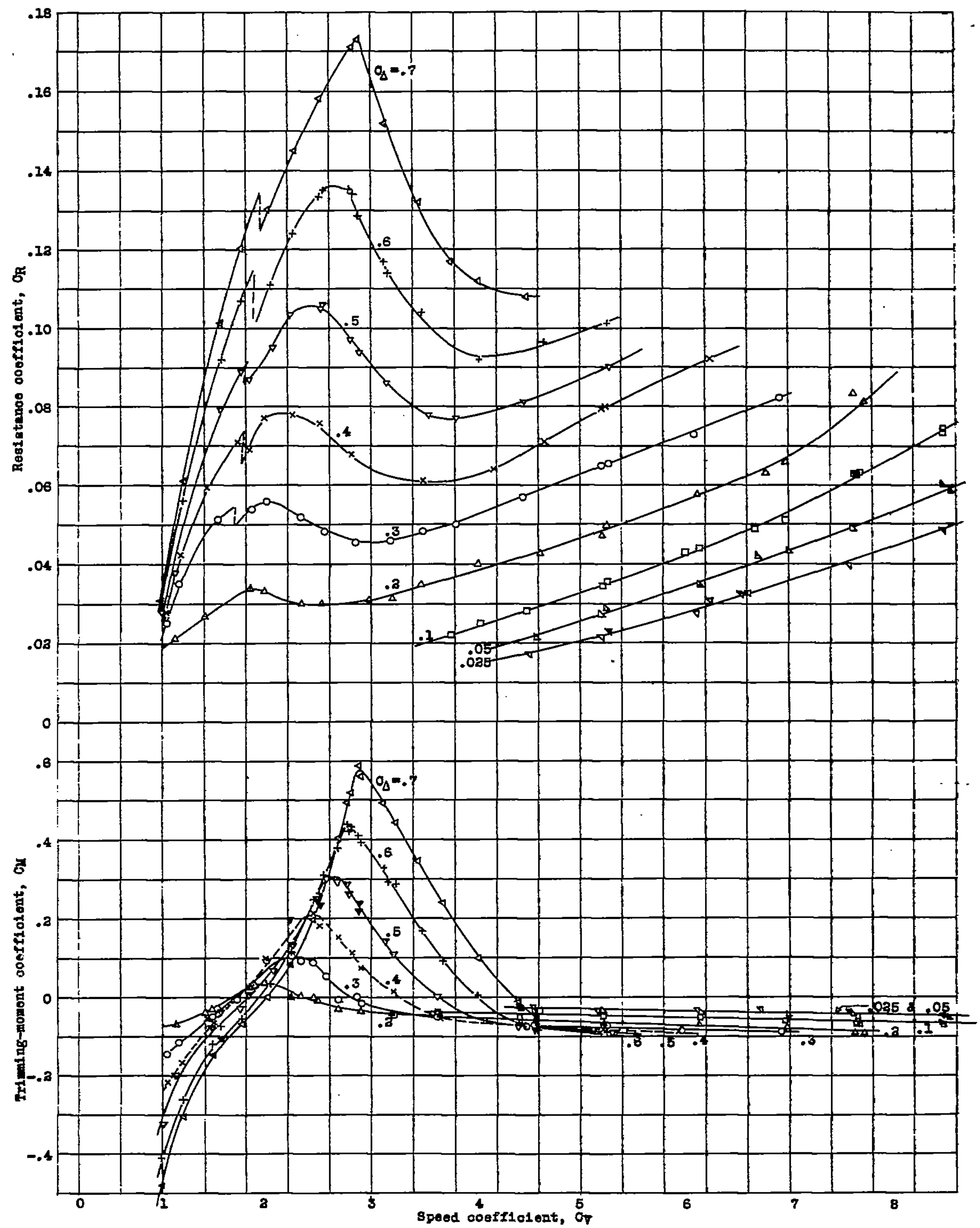


Figure 4.- Model 18. Variation of resistance coefficient and trimming-moment coefficient with speed coefficient. τ = 5°.

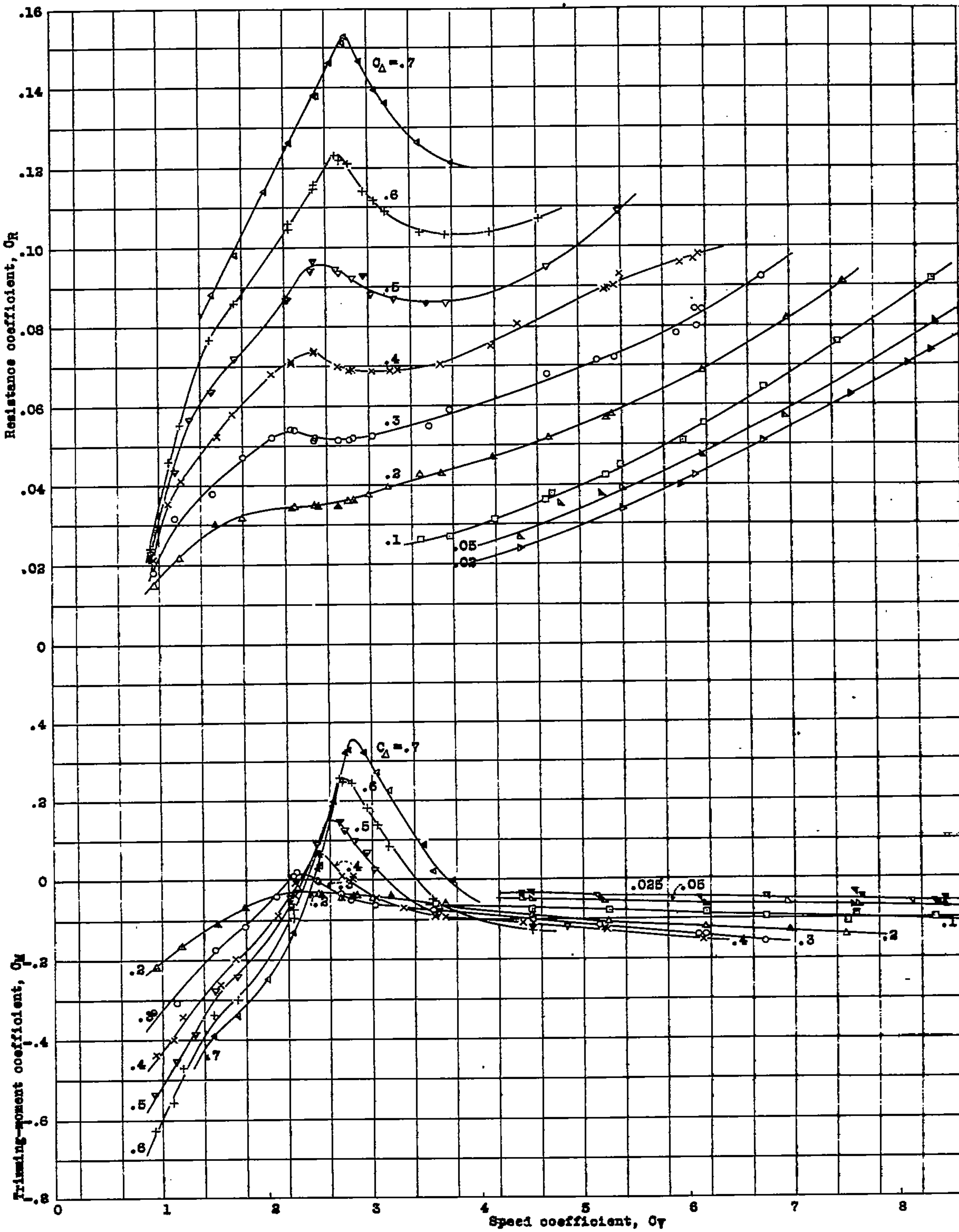


Figure 5.- Model 18. Variation of resistance coefficient and trimming-moment coefficient with speed coefficient. $\tau = 7°$.

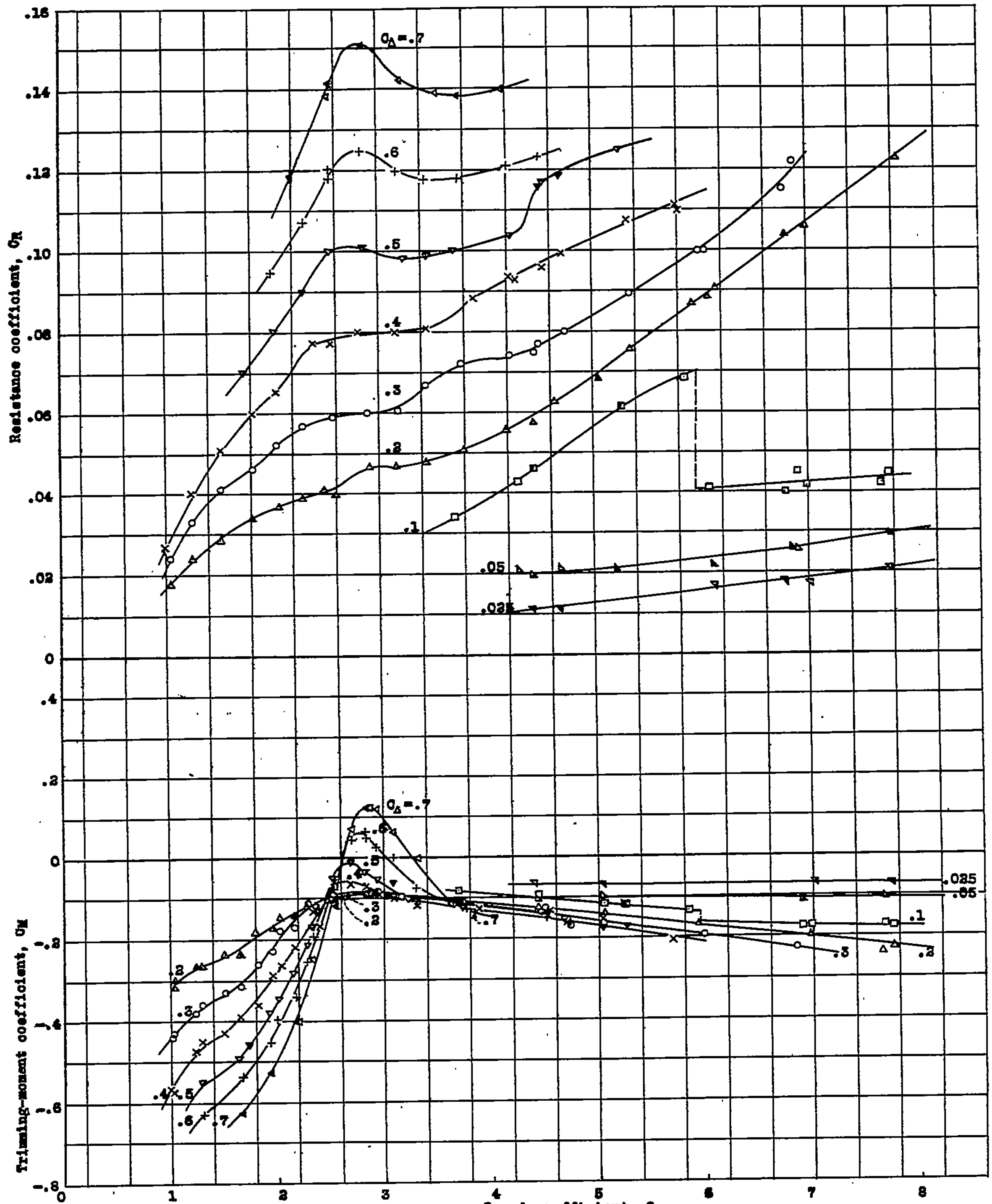


Figure 6.- Model 18. Variation of resistance coefficient and trimming-moment coefficient with speed coefficient. τ =9°.

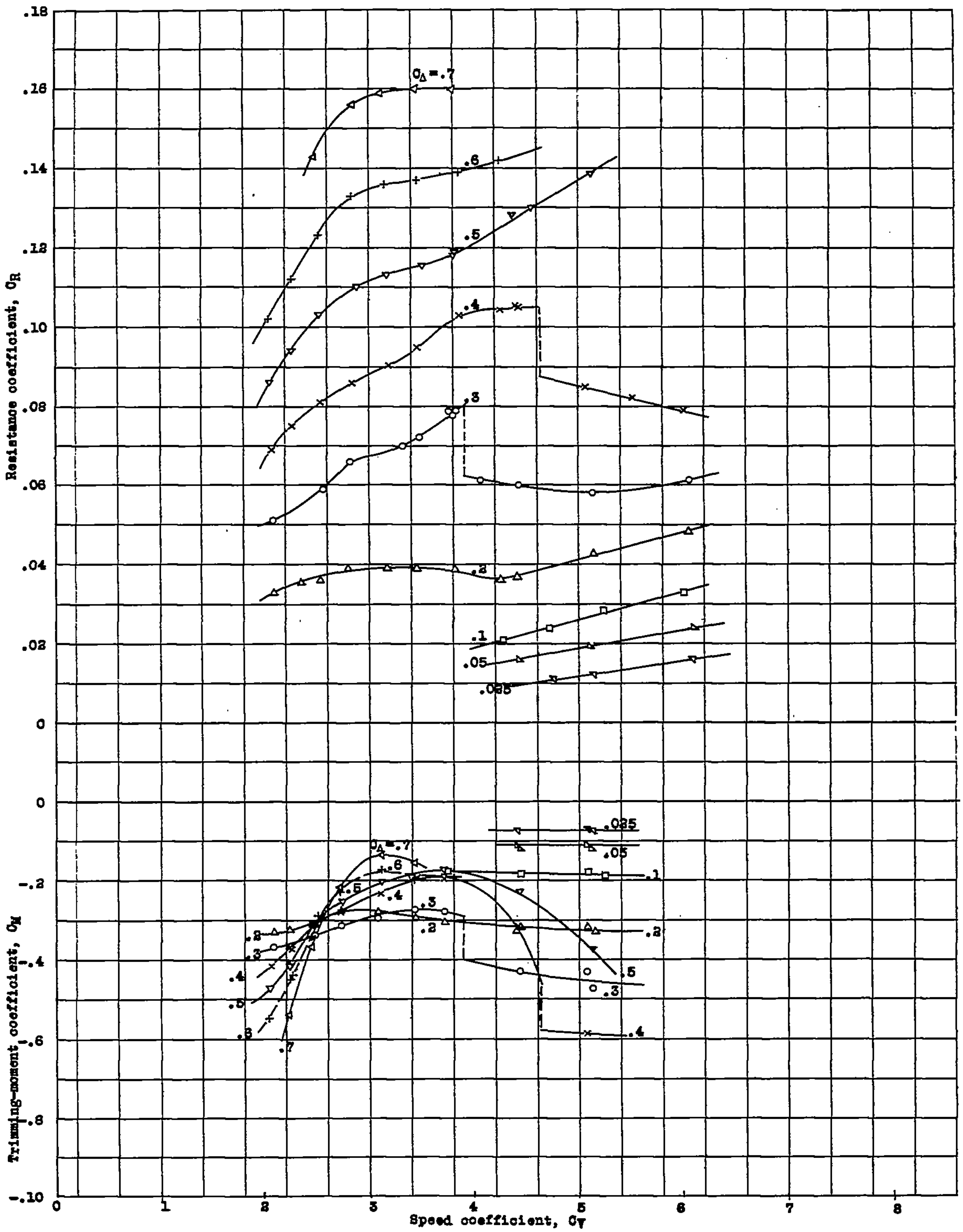


Figure 7.- Model 18. Variation of resistance coefficient and trimming-moment coefficient with speed coefficient. $\tau = 11°$.

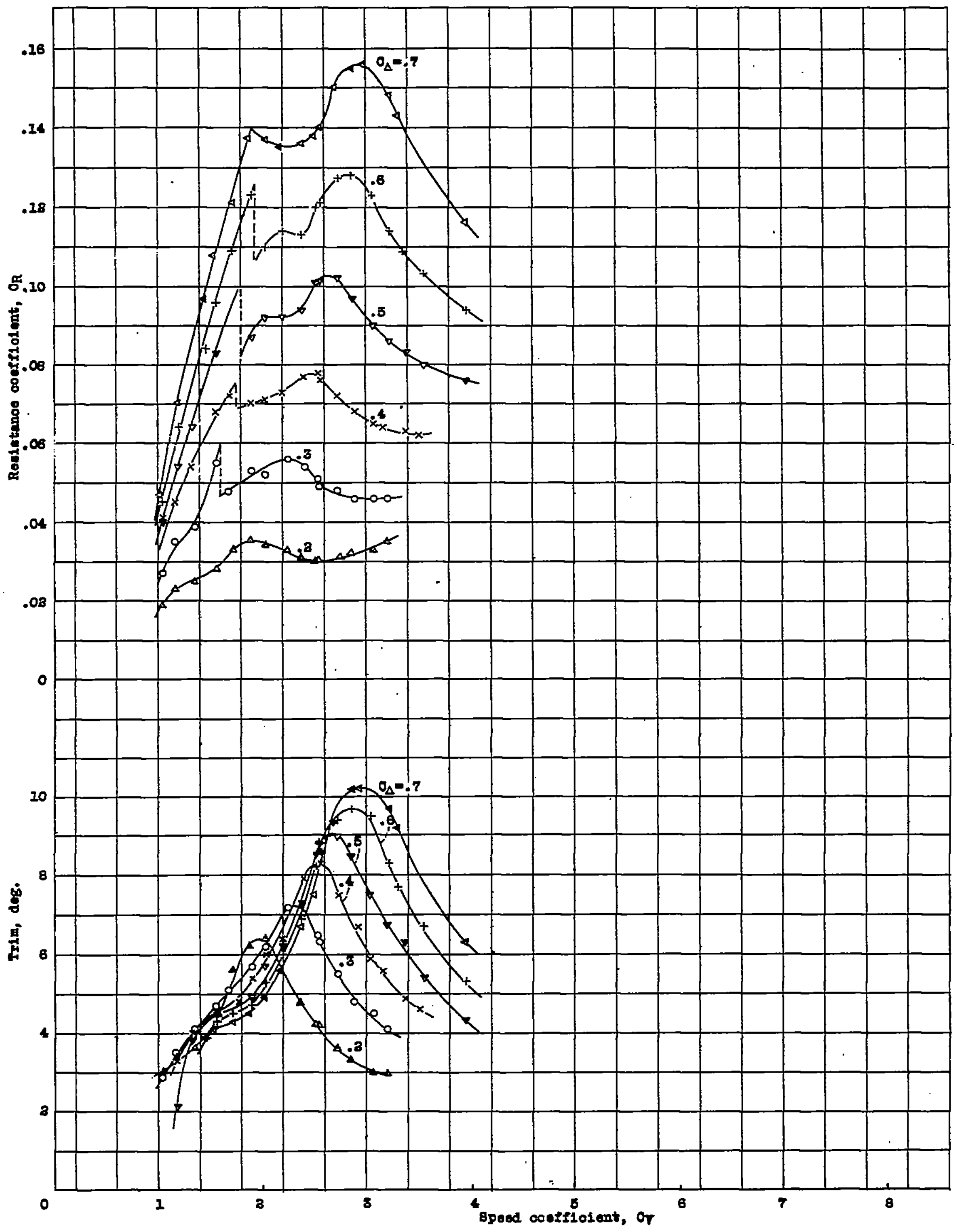


Figure 8.- Model 18. Variation of resistance coefficient and trim with speed coefficient. Free to trim. (From fig. 5, reference 3.)

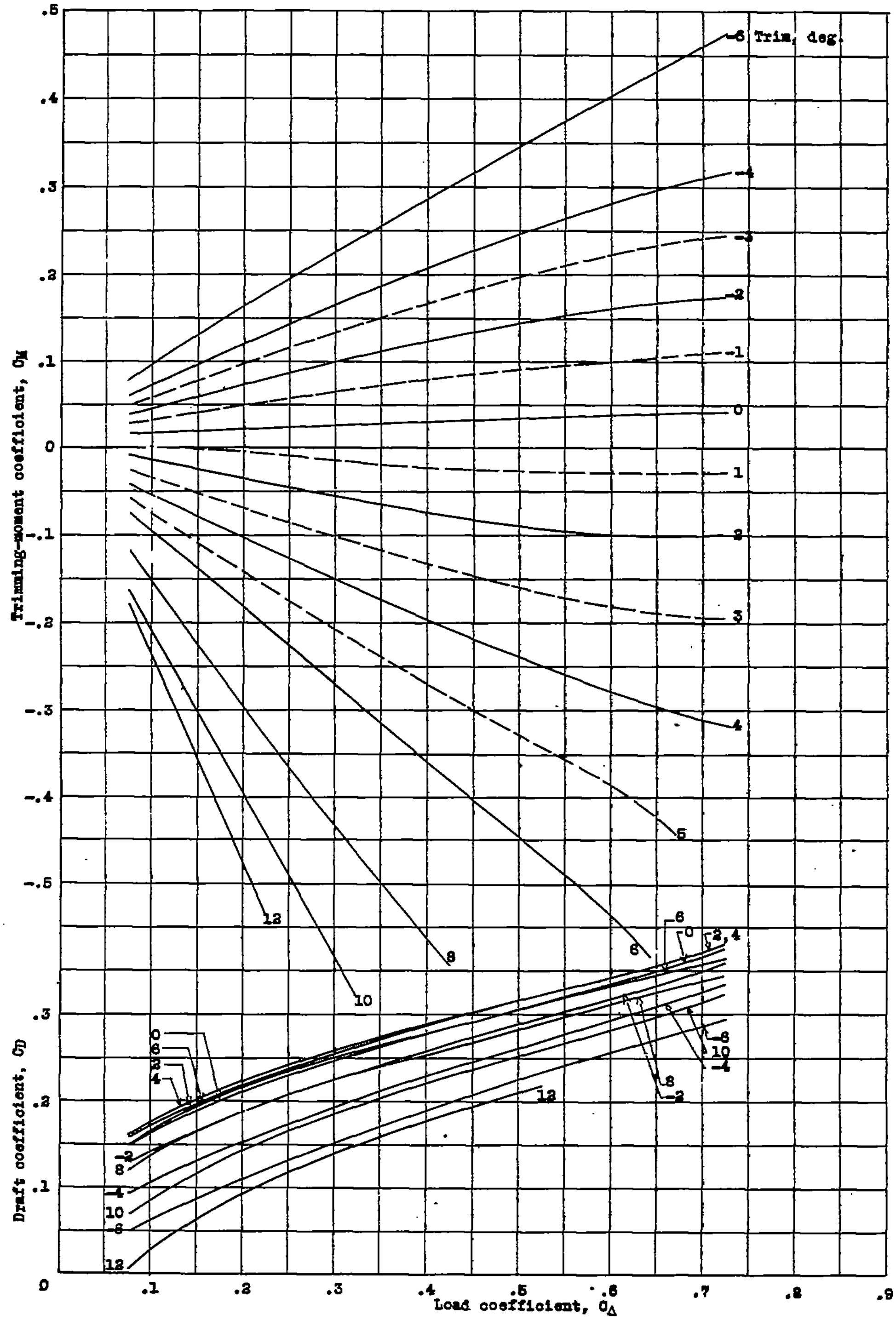


Figure 9.- Model 18. Static properties.

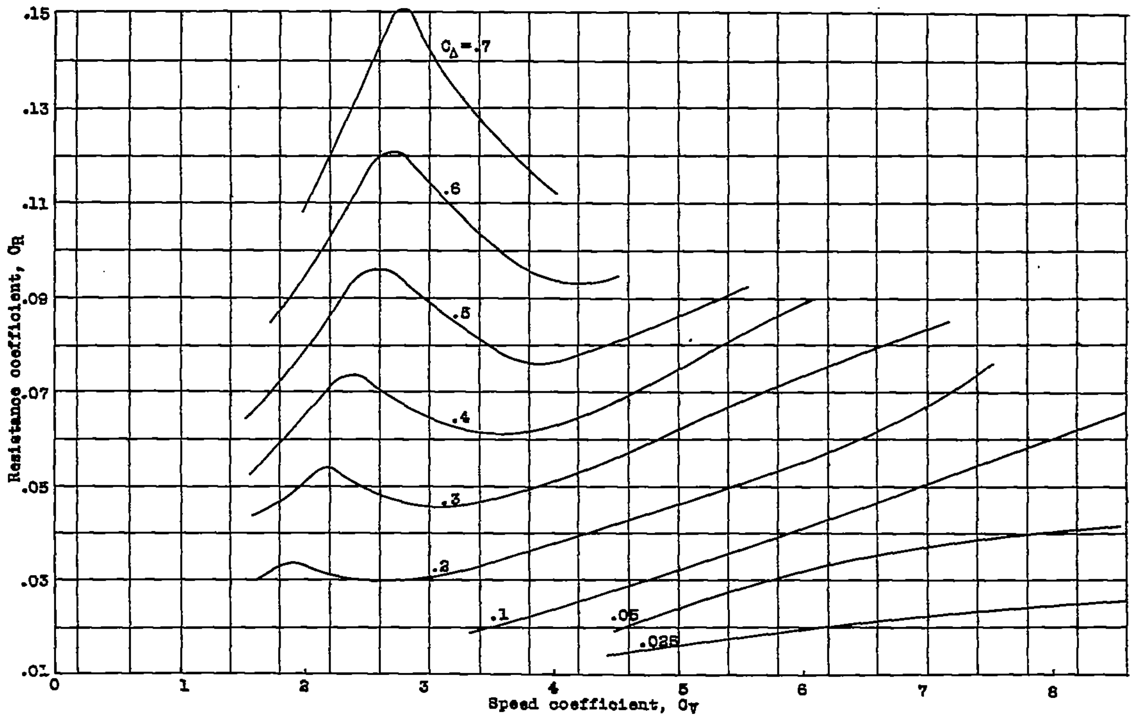


Figure 10.- Model 18. Variation of resistance coefficient at best trim with speed coefficient.

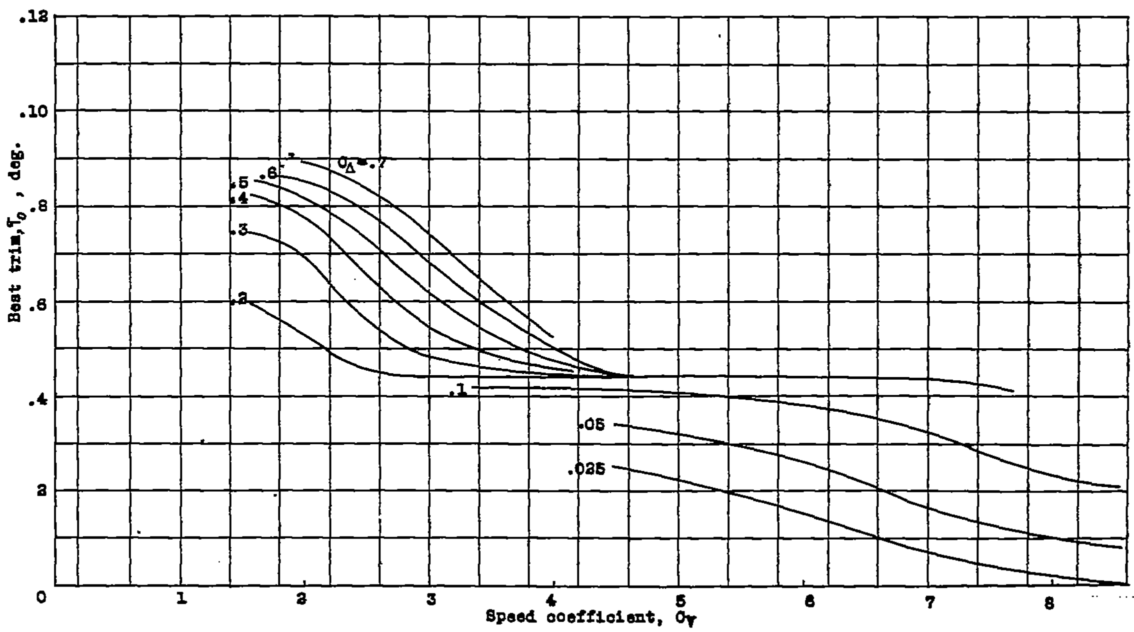


Figure 12.- Model 18. Variation of best trim with speed coefficient.

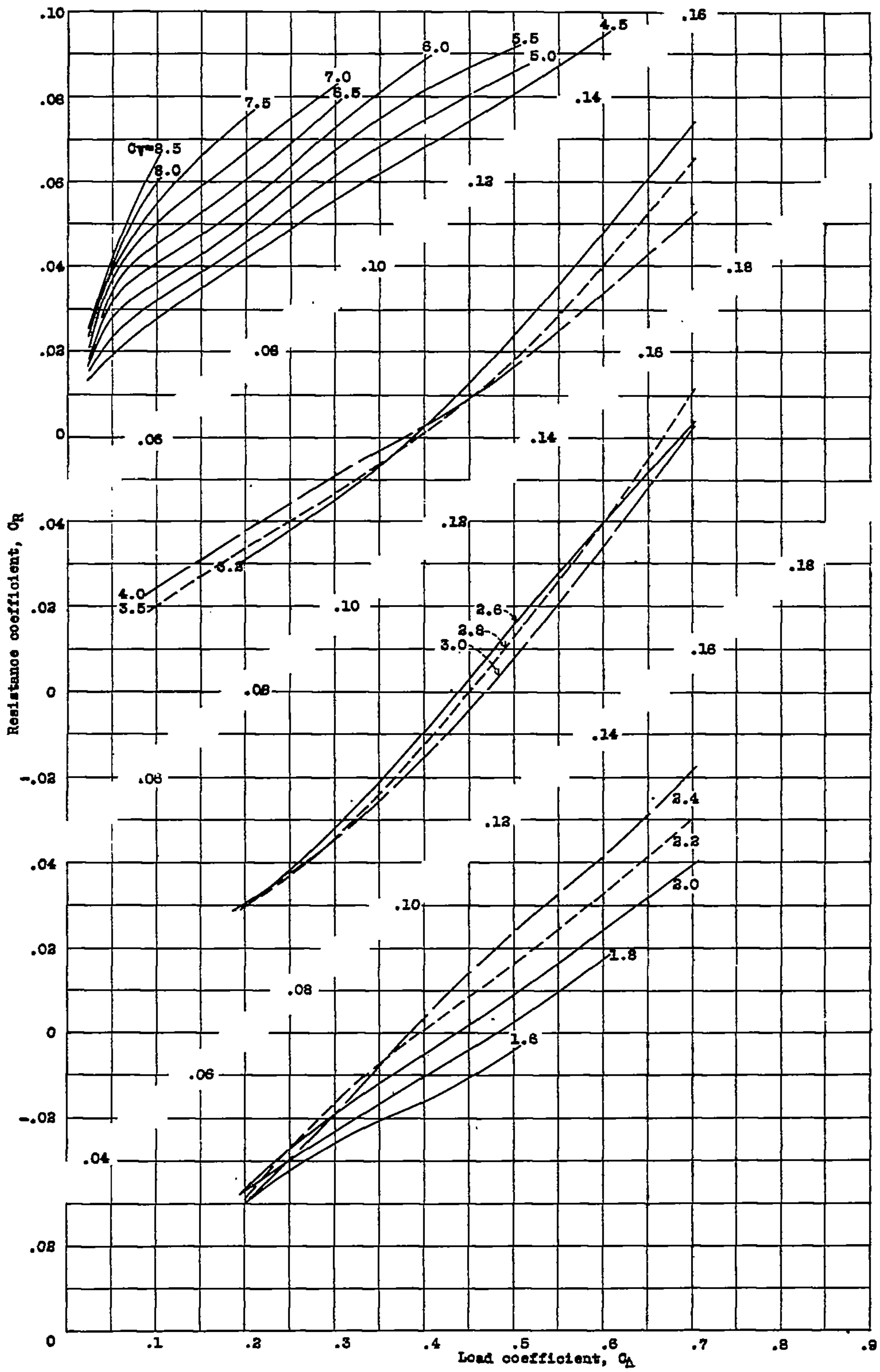


Figure 11.- Model 18. Variation of resistance coefficient at best trim with load coefficient.

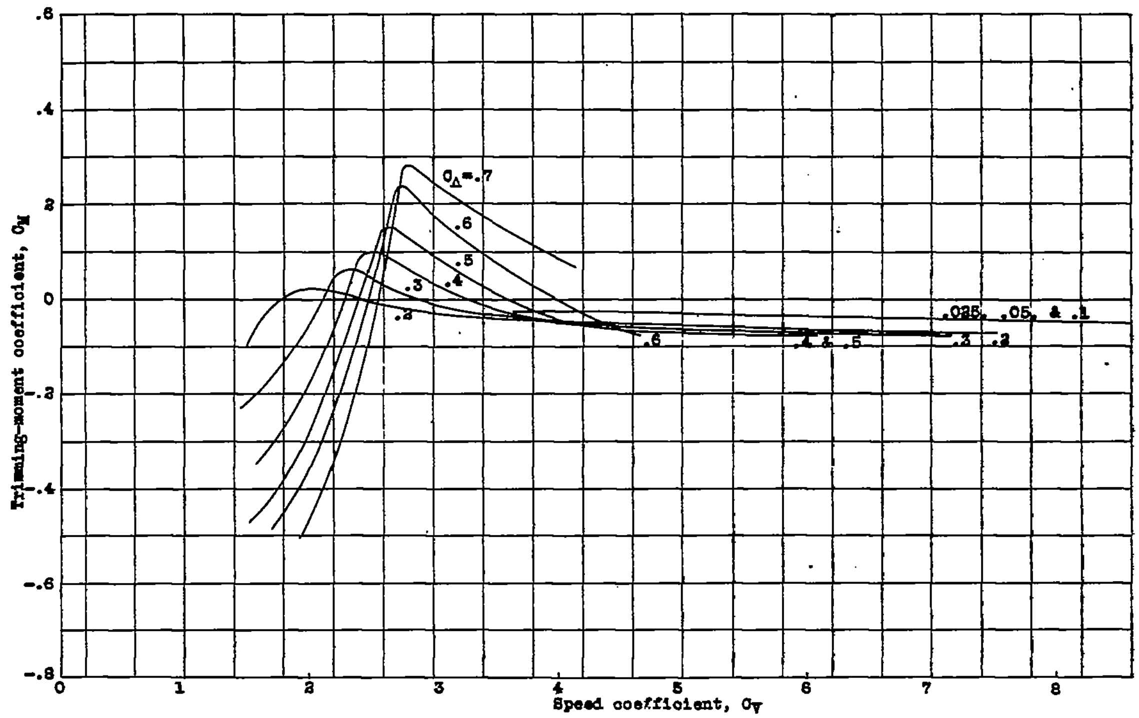


Figure 13.- Model 18. Variation of trimming-moment coefficient at best trim with speed coefficient.

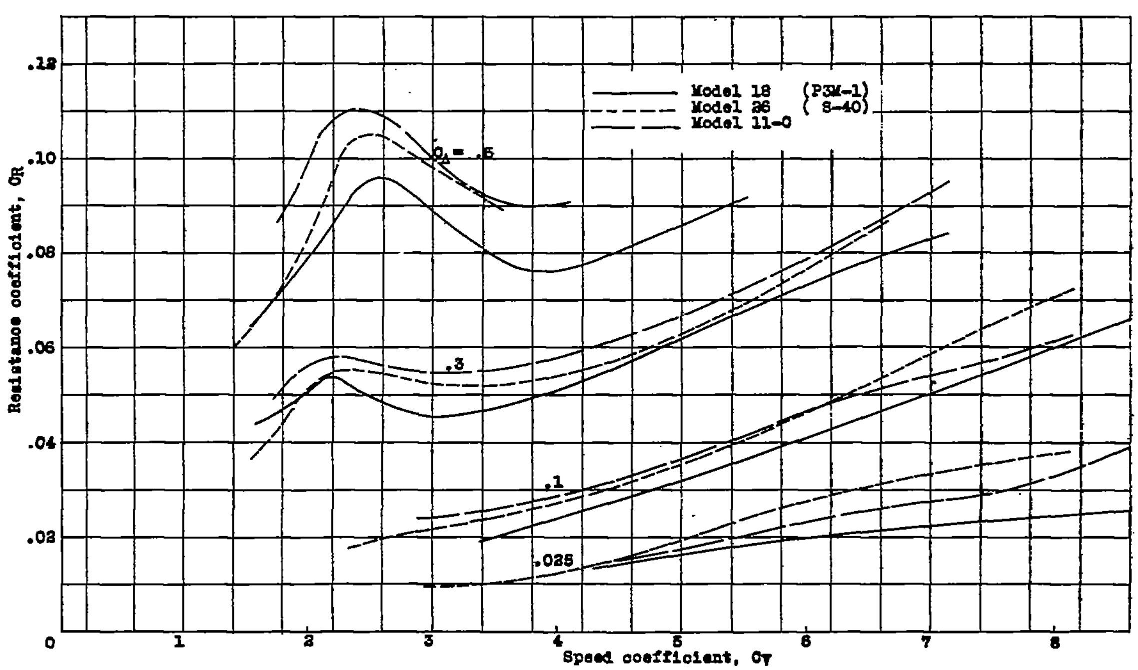


Figure 15.- Comparison of resistance coefficients at best trim of models 18, 26, and 11-C.

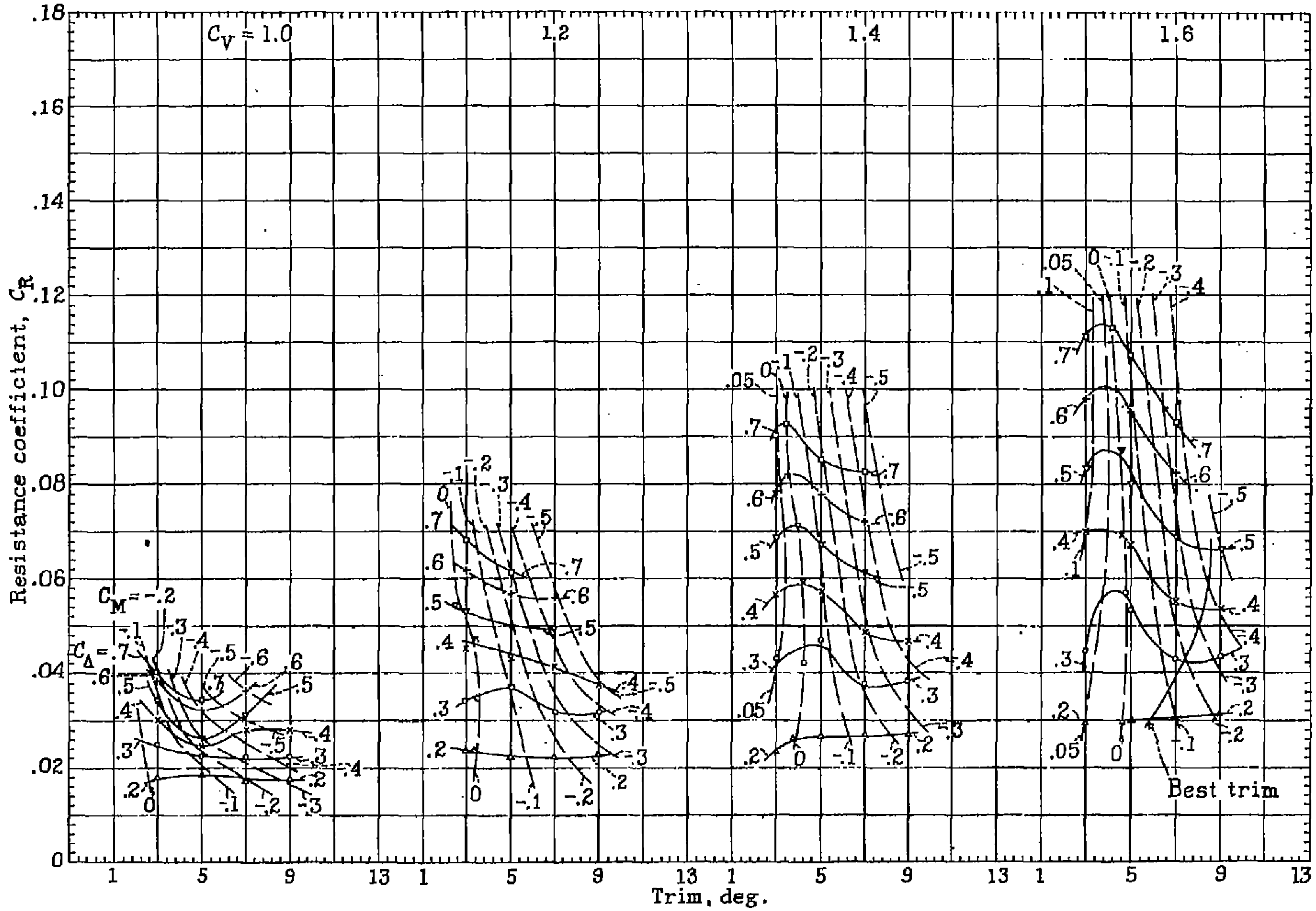
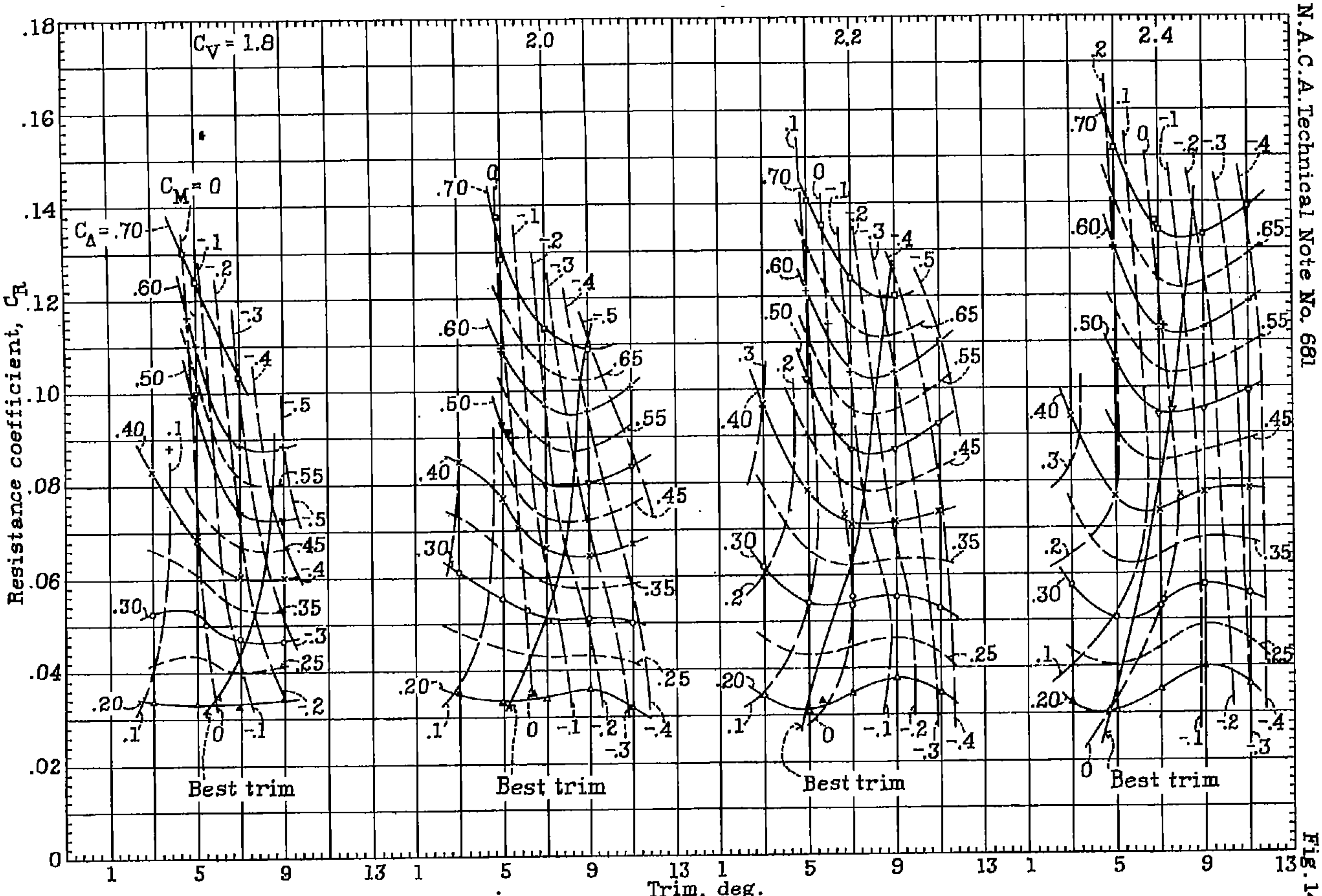


Figure 14a.- Model 18. Working charts for the determination of resistance and trimming moment.



N.A.C.A. Technical Note No. 681
Resistance coefficient, C_R
Trim, deg.
C_V = 1.8
2.0
2.2
2.4
C_M = 0
C_Δ = .70
Best trim
Fig. 14b

Figure 14b.

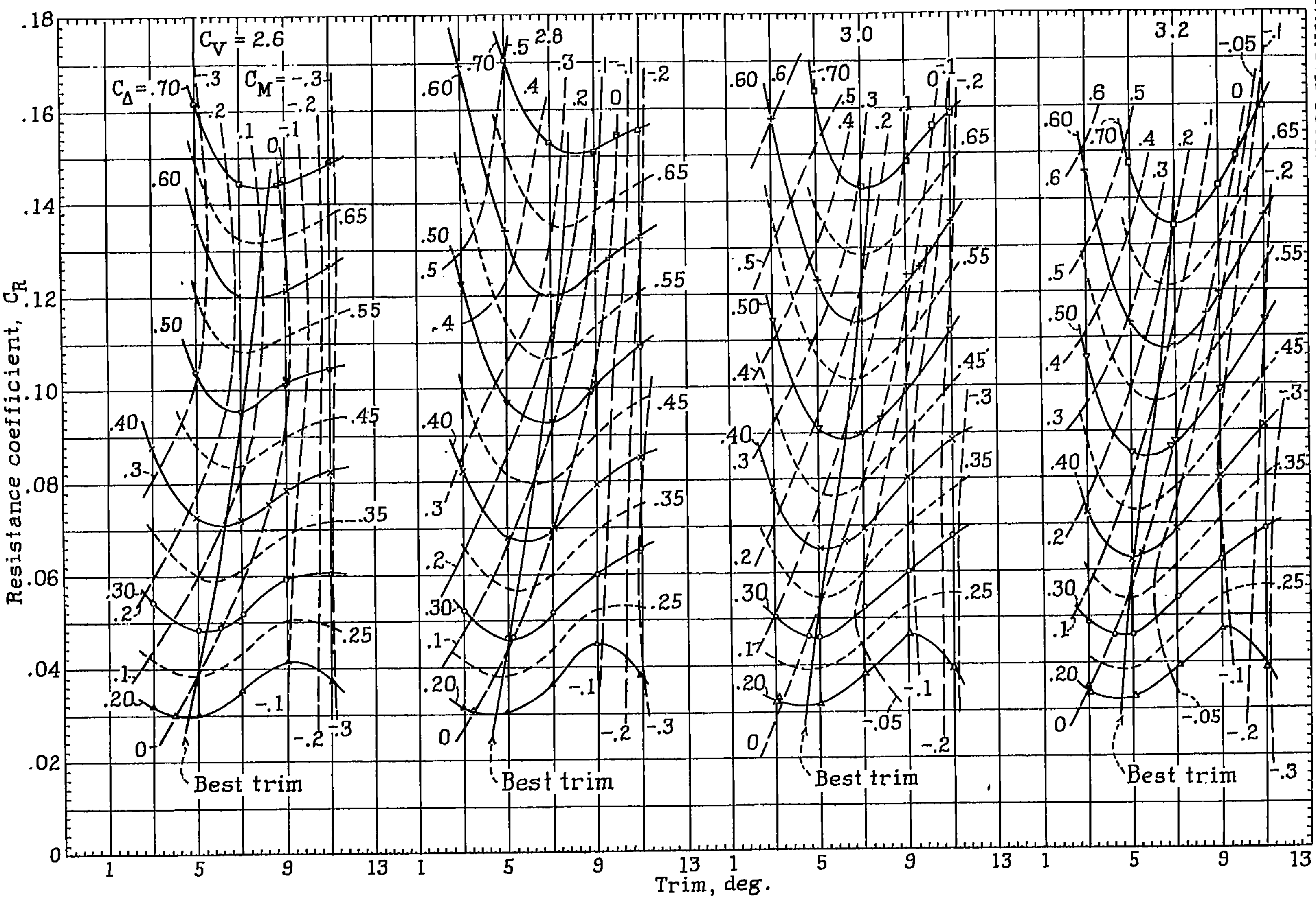

Resistance coefficient, C_R
Trim, deg.
C_V = 2.6
2.8
3.0
3.2
C_Δ = .70
C_M = -.3
Best trim
Best trim
Best trim
Best trim

Figure 14c.

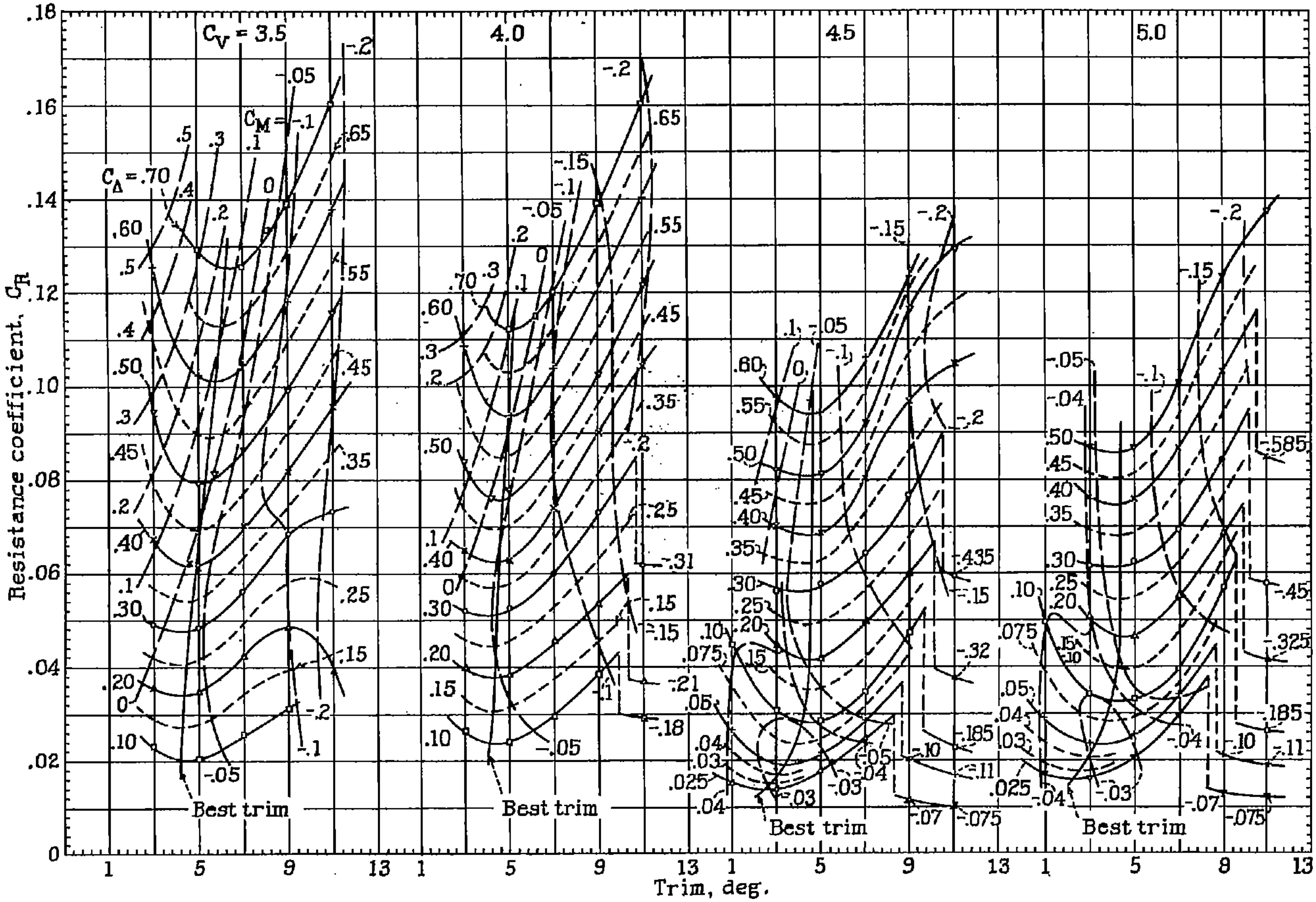

C_V = 3.5
4.0
4.5
5.0
C_M = -.1
C_Δ = .70
Best trim
Best trim
Best trim
Best trim
Resistance coefficient, C_R
Trim, deg.

Figure 14d.

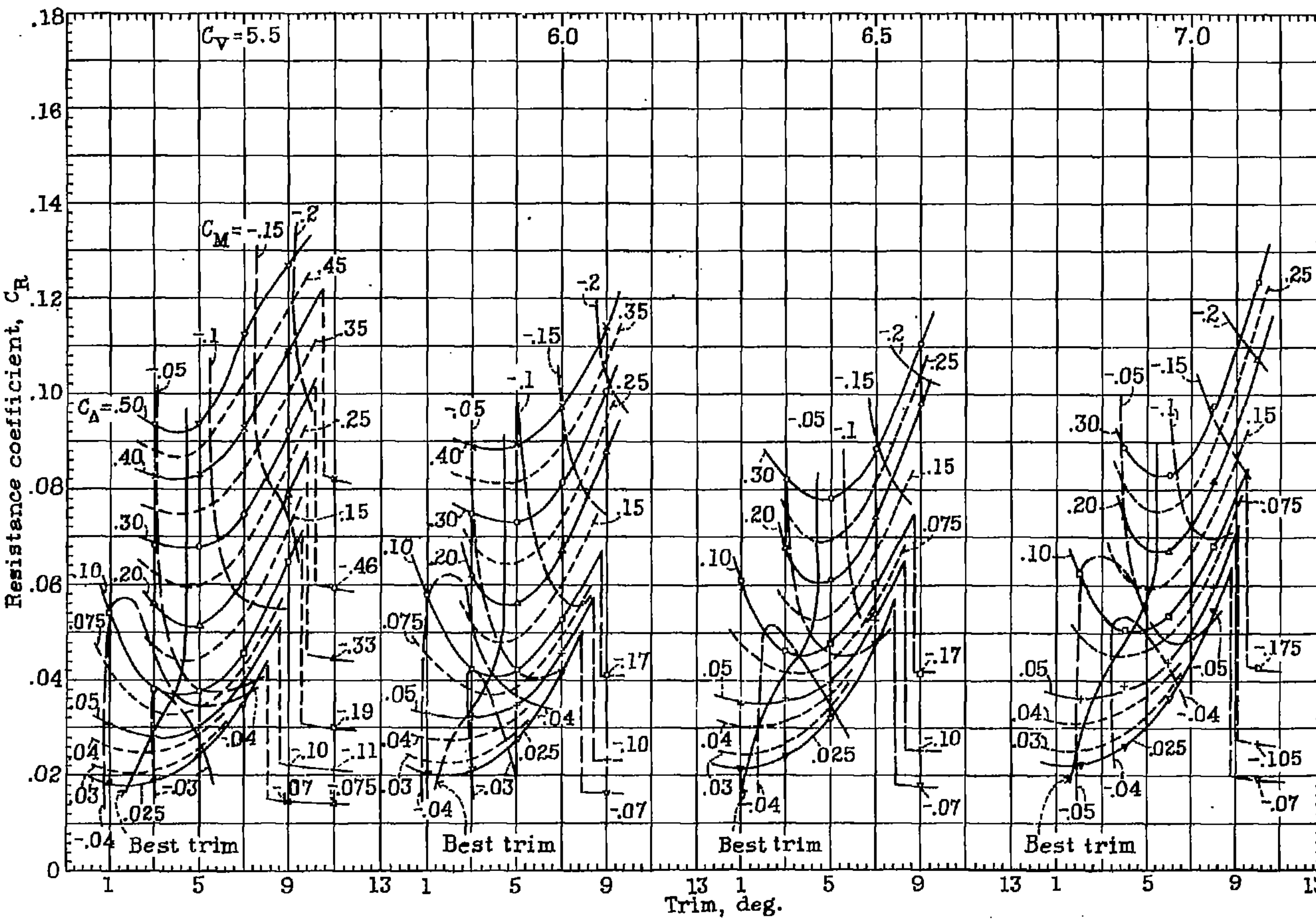
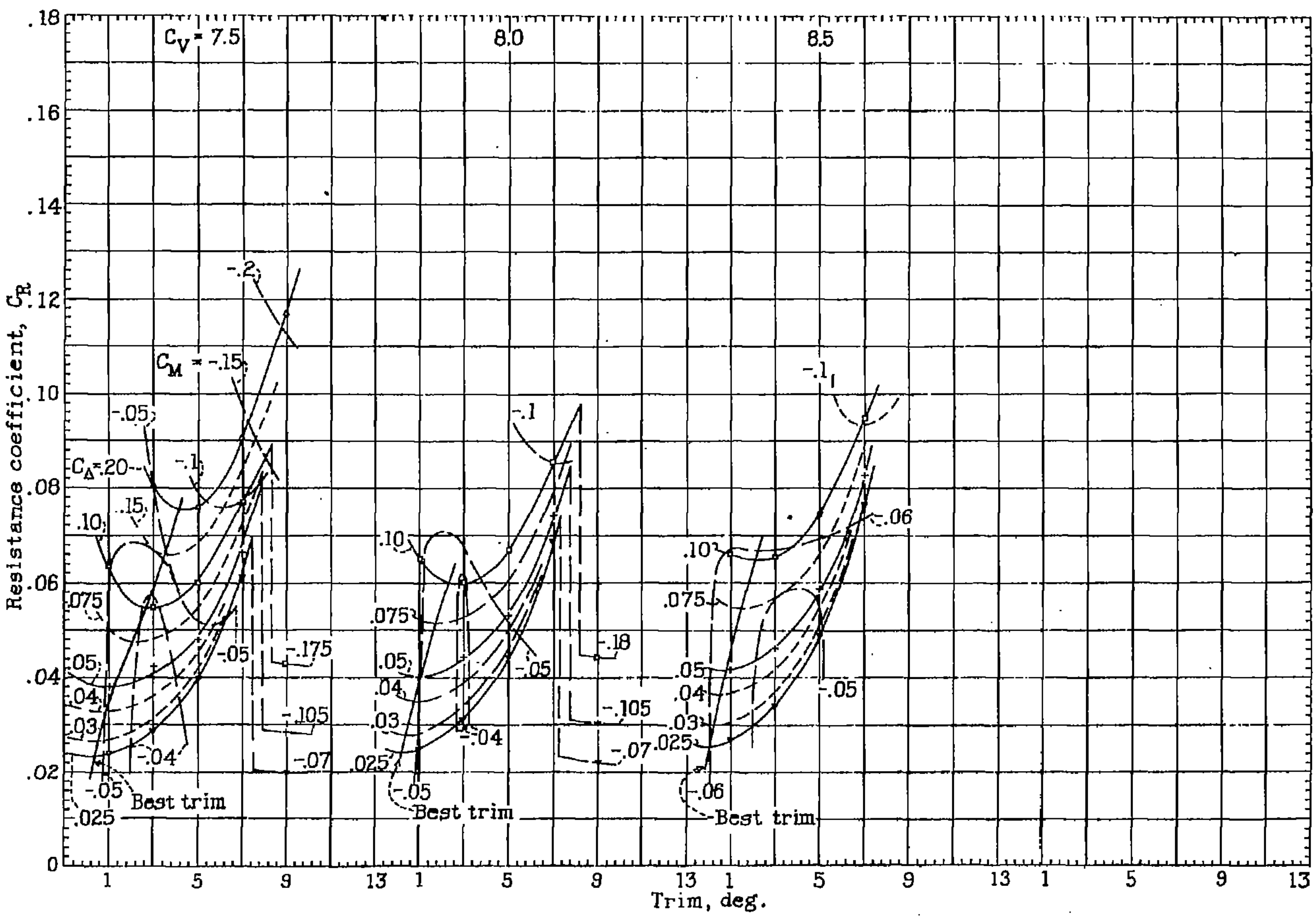

C_V=5.5
6.0
6.5
7.0
Resistance coefficient, C_R
Trim, deg.
Best trim
C_M=-.15
C_Δ=.50

Figure 14e.



Resistance coefficient, C_R
Trim, deg.
C_V = 7.5
8.0
8.5
C_M = -.15
C_Δ = .20
Best trim
Best trim
Best trim

Figure 14f.